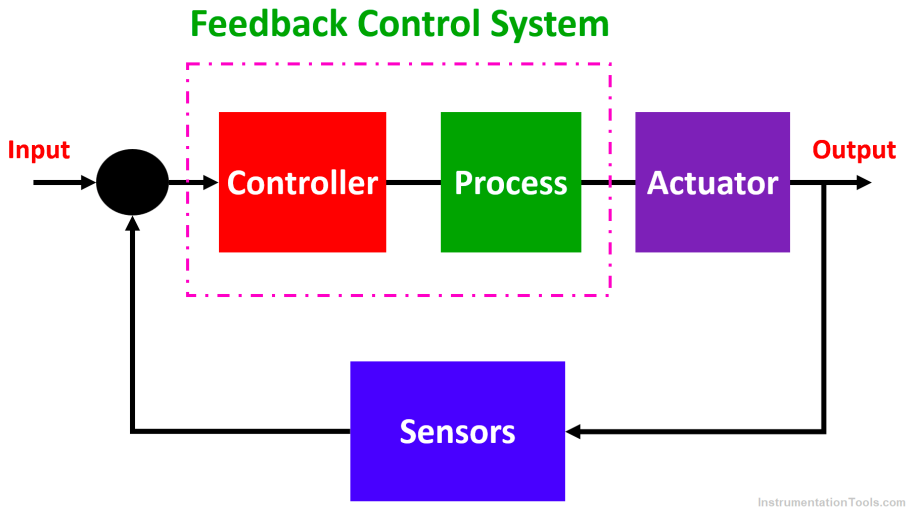
Electrical Signals

Control Systems

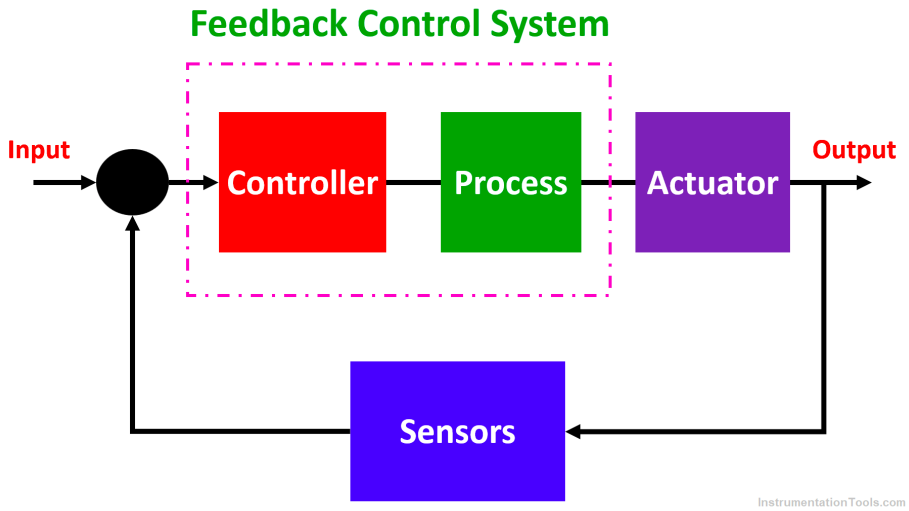
- A control system is a system that manages, commands, or regulates the behaviour of another system to achieve a desired output.

- It does this by:
  - Receiving input signals
  - Processing those signals
  - Producing an output that controls a device or process



Control Systems

- A typical control system consists of:
  - **Input** - The desired value or command (e.g. button press, set temperature)
  - **Controller** - Processes the input and decides what action to take(e.g. PLC, microcontroller, relay logic)
  - **Output / Actuator** - Carries out the action(e.g. motor, solenoid valve, hydraulic or pneumatic cylinder)



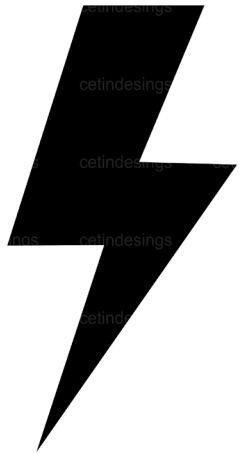
What are signals

- A signal is a measurable quantity used to **communicate information** within a system. (between components)
- Signals do not usually do work themselves — they tell another part of the system what to do.
- Examples of signals:
  - Voltage level from a sensor
  - ON/OFF state of a switch
  - Pressure signal in a pneumatic control line
  - PWM signal controlling motor speed

What is power transmission

- Power transmission is the transfer of energy to perform work.

- **It is responsible for:**
  - Movement
  - Force
  - Heat
  - Mechanical output

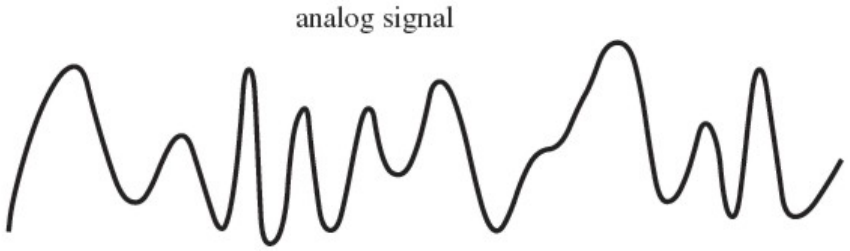


- **Examples of power transmission:**
  - Electrical power driving a motor
  - Hydraulic pressure moving a ram
  - Pneumatic air pressure extending a cylinder
  - Mechanical shafts and gears transferring torque

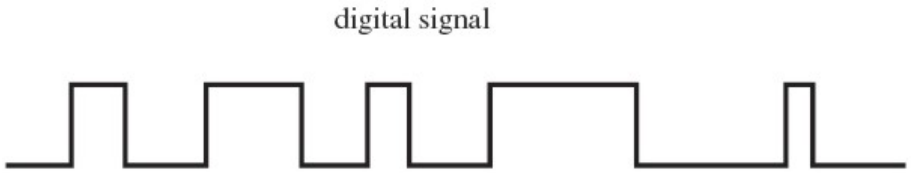
Analogue vs Digital signals

Signals (particularly electrical) can be categorised into two categories:

- Analogue signals are continuous and change smoothly over time (for instance 2.5v to 3.4v)

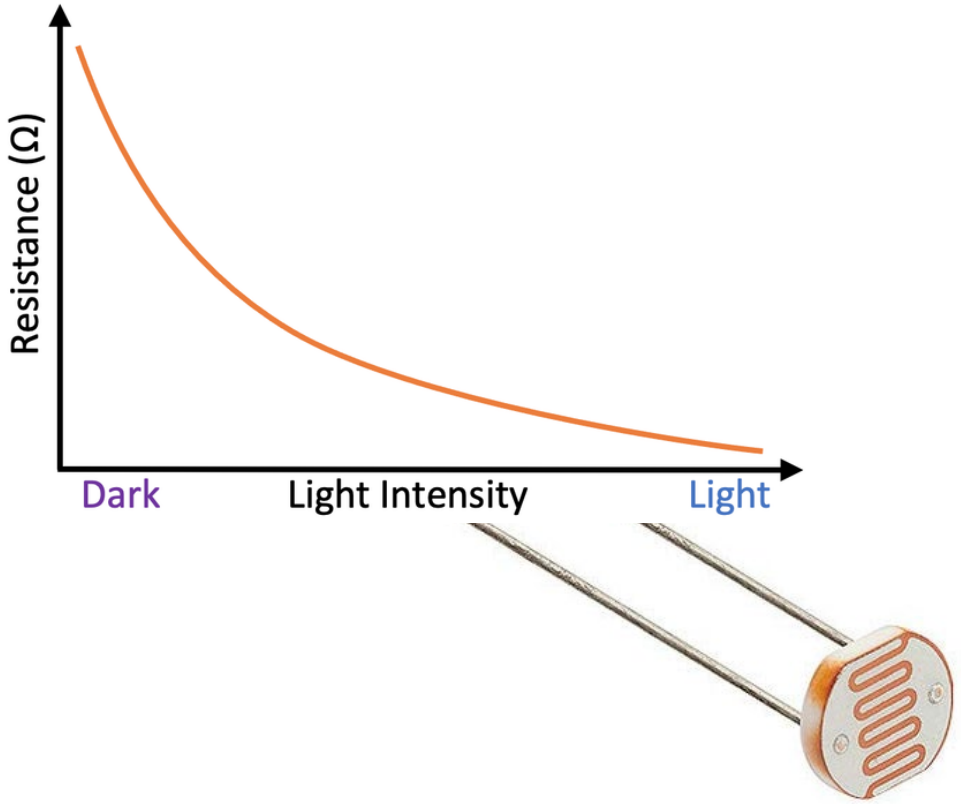


- Digital signals are discrete and therefore have set values which they change between (for instance on or off)



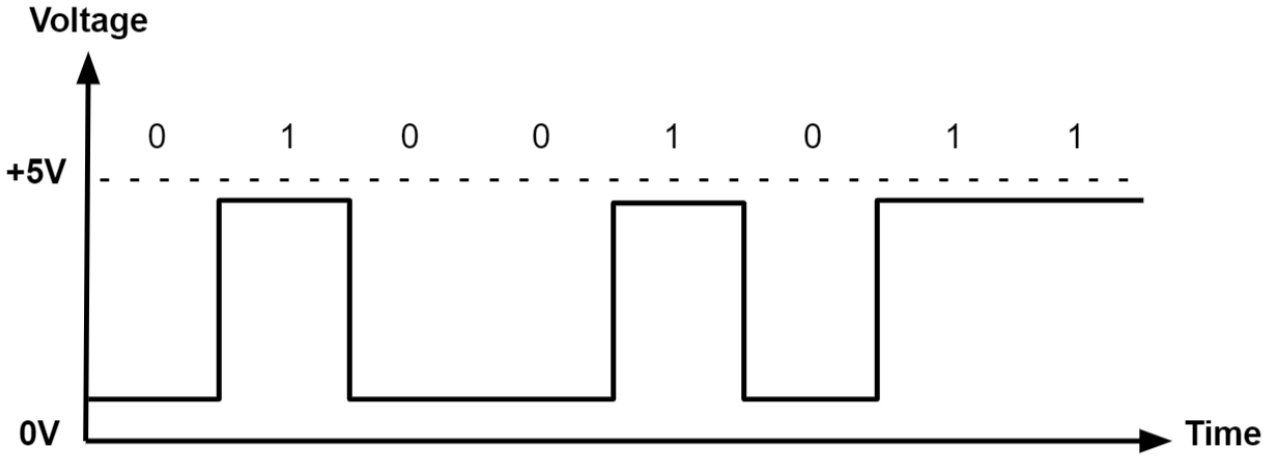
Example of an analogue signal

- **Light Sensor (e.g., LDR)**
- Produces a voltage that varies continuously based on light intensity.
- It does this by varying resistance based on the light hitting the LDR which relates directly to voltage
- This voltage then can be read by a microcontroller



Example of a digital signal

- **Push Button or Switch**
- Outputs either HIGH (1) or LOW (0) depending on whether the switch is pressed.
- It does this by completing the circuit when the button is pressed
- A microcontroller can detect when a voltage is input and when it isn't



Your turn

Determine whether these components are digital or analogue and whether they are input or output:

Switch	Motor speed control
Relay	Micro-switch
Thermocouple	Solenoid
Pressure sensor	A moving coil meter
Variable flow valve	Proximity Switch
Motor ON/OFF	Optical Sensor
Current Loop	LED

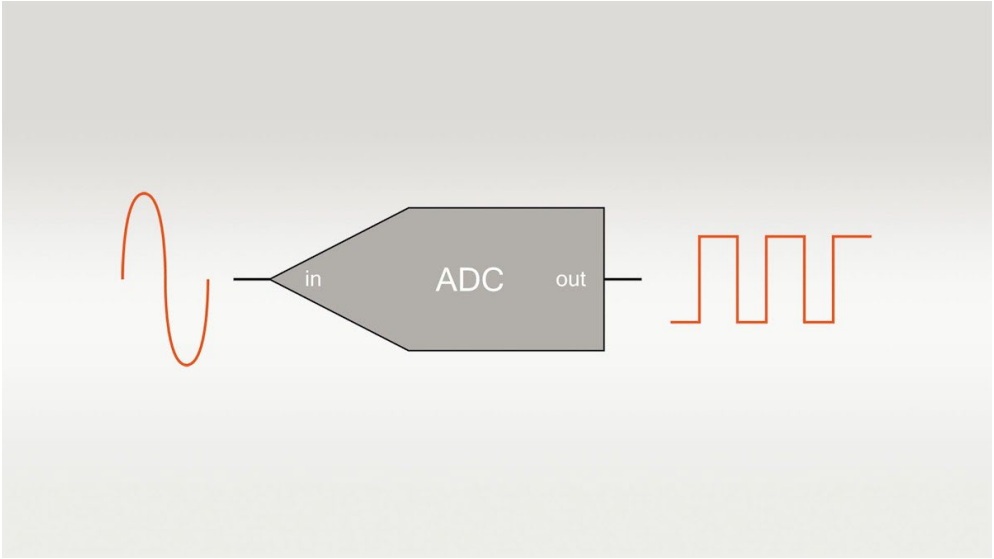
Your turn - Answers

Determine whether these components are digital or analogue and whether they are input or output:

Switch	Motor speed control
Relay	Micro-switch
Thermocouple	Solenoid
Pressure sensor	A moving coil meter
Variable flow valve	Proximity Switch
Motor ON/OFF	Optical Sensor
Current Loop	LED

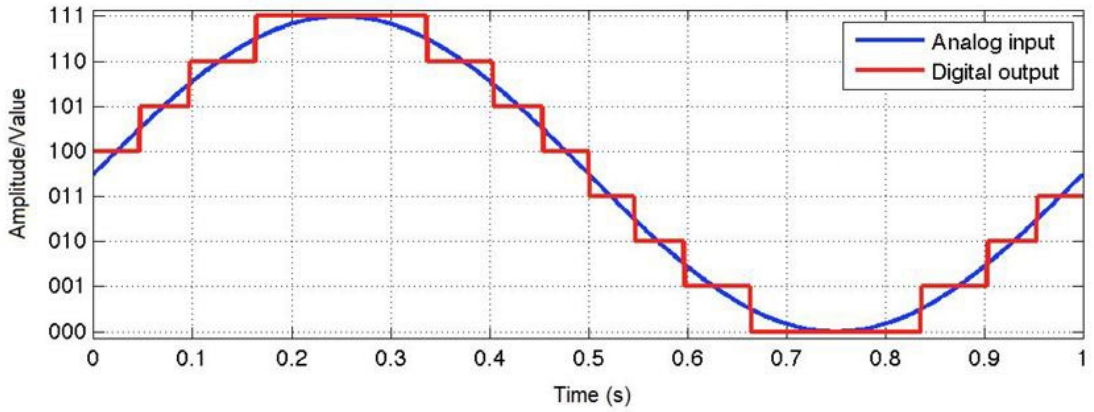
Microcontrollers and Analogue Signals

- Most controllers only understand digital logic as they use binary logic
- So, when putting an analogue signal into a controller you must change it into a digital signal
- This is done using an ADC or Analogue to Digital Converter



Analogue to Digital Converter

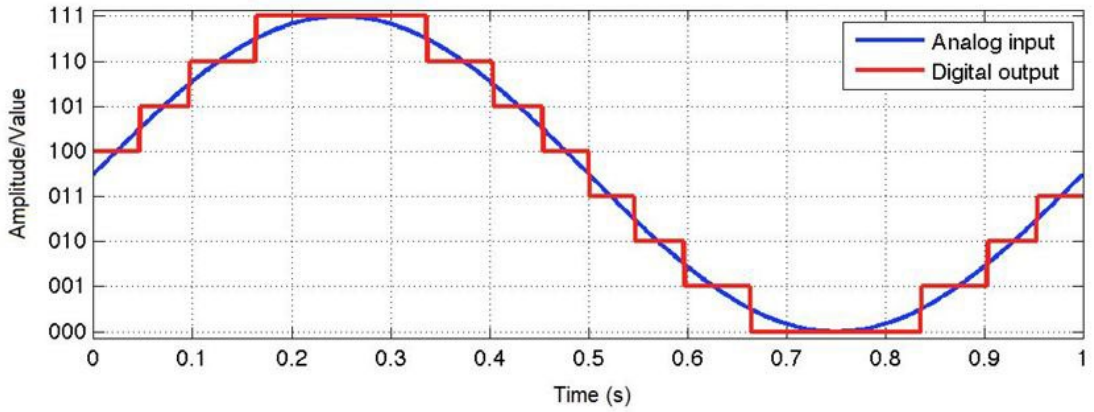
- An ADC converts and analogue signal to digital by having “steps”
- Each of these steps are equal to a certain range of values in an analogue signal
- The wave is then sampled where points are taken from it and rounded to these steps



Analogue to Digital Converter

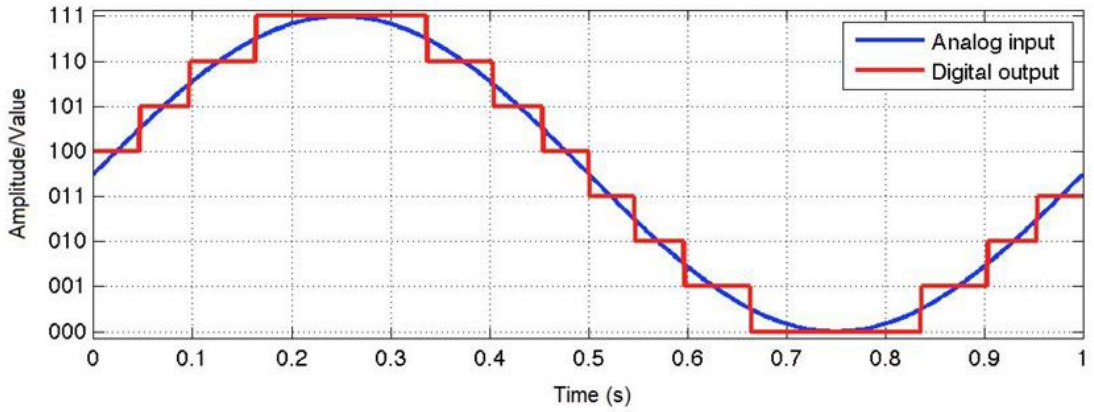
- So an ADC follows this process:

- **Sampling**: The ADC measures the analogue signal at regular intervals.
- **Quantization**: The sampled values are rounded to the nearest digital level.
- **Encoding**: The values are stored as binary numbers (e.g., 8-bit, 10-bit, etc.).



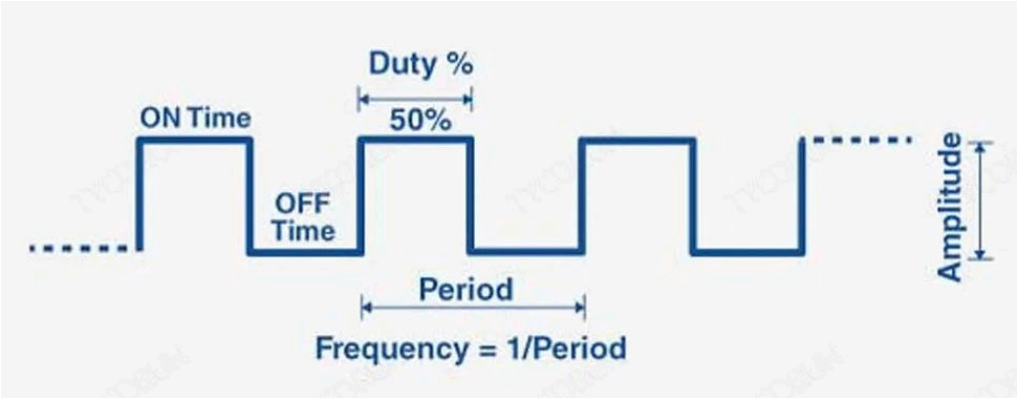
ADC Resolution

- The resolution of ADC is the number of steps a wave will be converted to
- For an 8-bit ADC a wave is split into 256 separate values (2^8)
- For a 10-bit ADC a wave is split into 1024 separate values (2^{10})
- Higher resolution means the ADC is more accurate, but the controller needs more processing power



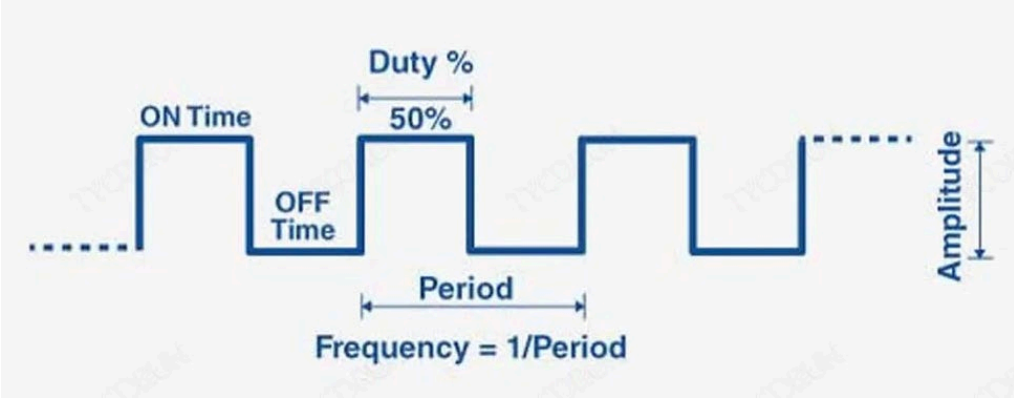
What is PWM

- A technique to control power by rapidly switching a signal between ON and OFF states.
- Simulates an analogue output using a digital signal
- Used for controlling motors, LEDs, and power regulation



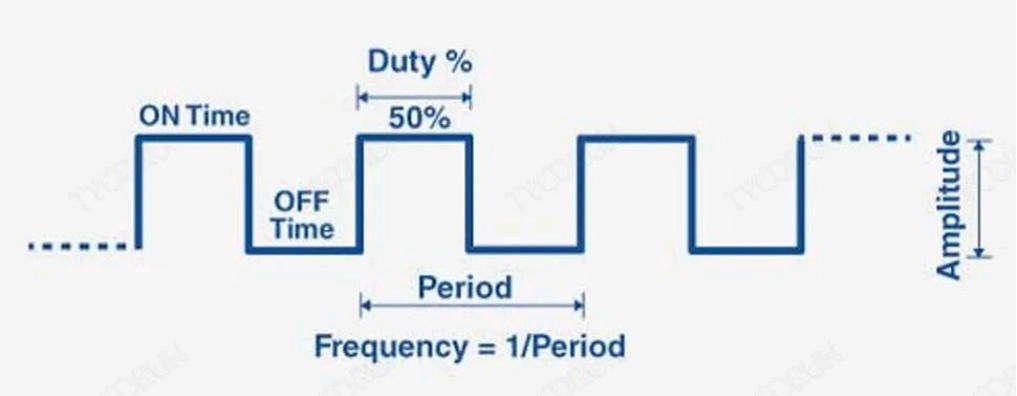
Parts of a PWM

- The duty cycle determines what percentage of the wave is “on”
- This can be worked out by:
- Duty Cycle (%) = (Time HIGH / Total Period) × 100
- 100% Duty Cycle → Always ON (Full Power)
- 50% Duty Cycle → ON half the time (Half Power)
- 0% Duty Cycle → Always OFF (No Power)



PWM Frequency

- How fast the signal switches ON and OFF (measured in Hz).
- Higher frequency = smoother control (important in motors & audio signals).
- Lower frequency = flickering or choppy motion in certain applications.



PWM Applications

LED Dimming – Adjust brightness without changing voltage.

Motor Speed Control – DC motors respond to different duty cycles.

Servo Motors – PWM signals determine precise angular positions.

Audio Signals & Power Supplies – Used in digital sound processing and voltage regulation.

Communication Systems – Used in encoding signals for wireless communication.